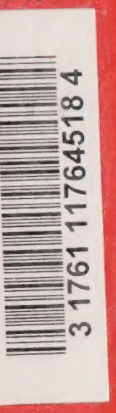


Indian and Northern Affairs Canada
Affaires indiennes et du Nord Canada

WOLF CREEK RESEARCH BASIN, YUKON

ARCTIC ENVIRONMENTAL STRATEGY • STRATEGIE POUR L'ENVIRONNEMENT ARCTIQUE
CANADA'S GREEN PLAN
LE PLAN VERT DU CANADA

Canada

Published under the authority of the
Minister of Indian Affairs and
Northern Development,
Ottawa, 1993.

QS- QS#Y090-000-EE-A1

Catalogue Number: R71-51/1993E

ISBN # 0-662-21223-1

Minister of Supply and Services Canada
December 1993

Front photo courtesy of John Pomeroy, NHRI

INTRODUCTION

The Wolf Creek Research Basin project was initiated in 1992 to provide a dedicated site to carry out applied research in the Yukon sub-Arctic. The initiative was funded by the Indian and Northern Affairs Canada (DIAND) Arctic Environmental Strategy Program (AES) with support from Environment Canada's National Hydrology Research Institute (NHRI). The AES program has the broad objective of establishing an enhanced water management regime by improving the Department's knowledge of Yukon waters and by measuring changes in Yukon waters.

Significant support and assistance was provided by NHRI, who have a strong research interest in developing improved snow accumulation, snowmelt and regional evapotranspiration routines for hydrologic modelling purposes.

Several other agencies are also interested in collaborating in the project. Notably the Institut National de la Recherche Scientifique (INRS) at the University of Quebec, who represent a group of researchers from several Canadian universities, have a proposal through the World Climate Research Program's Global Energy and Water Cycle Experiment (GEWEX), to carry out research in the basin. Yukon College and the Northern Research Institute are also interested in cooperating where possible.

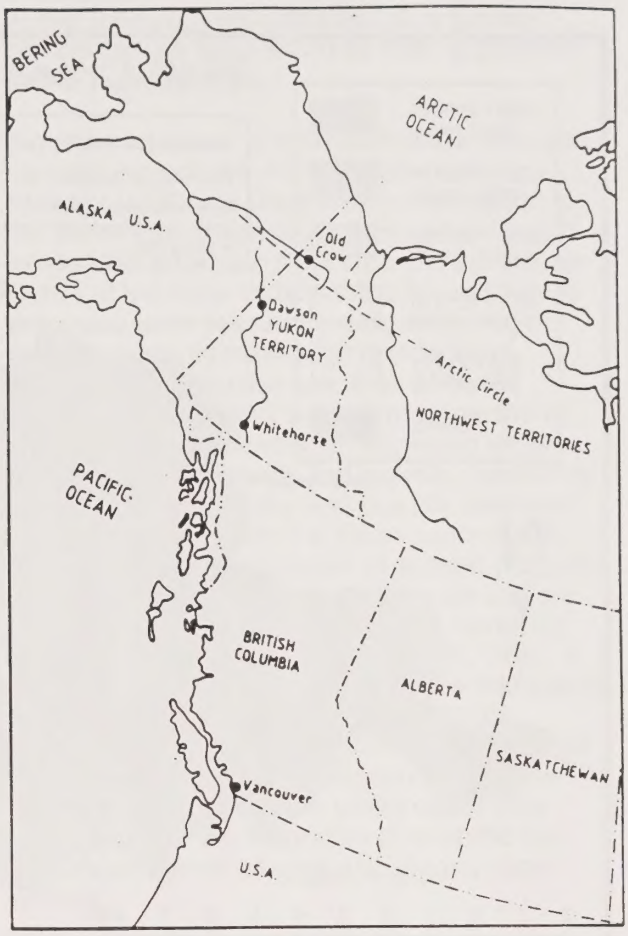
Logistically the Wolf Creek basin is a very attractive research site since it is located within thirty minutes of Whitehorse. The basin is readily accessible by truck in the summer and snowmobile in the winter. Technical and scientific staff with maintenance and troubleshooting capabilities are located in Whitehorse.

STUDY AREA

The Wolf Creek basin is located 15 kilometres south of Whitehorse, Yukon Territory at approximately 61 degrees north latitude (figure 1). The lower reaches are easily accessible by the Alaska Highway and other all weather roads. The middle and upper reaches are accessible by a good summer road which also acts as an excellent snowmobile trail during the winter months.

The basin occupies a 220 km^2 area in the southern Yukon headwater region of the Yukon River (figure 2). With a northeasterly aspect, elevations range from 800 to 2250 metres with the median elevation at 1325 metres (figure 3). Besides some small headwater cirque lakes and small upland wetlands, the watershed has one major storage element, Coal Lake, which is

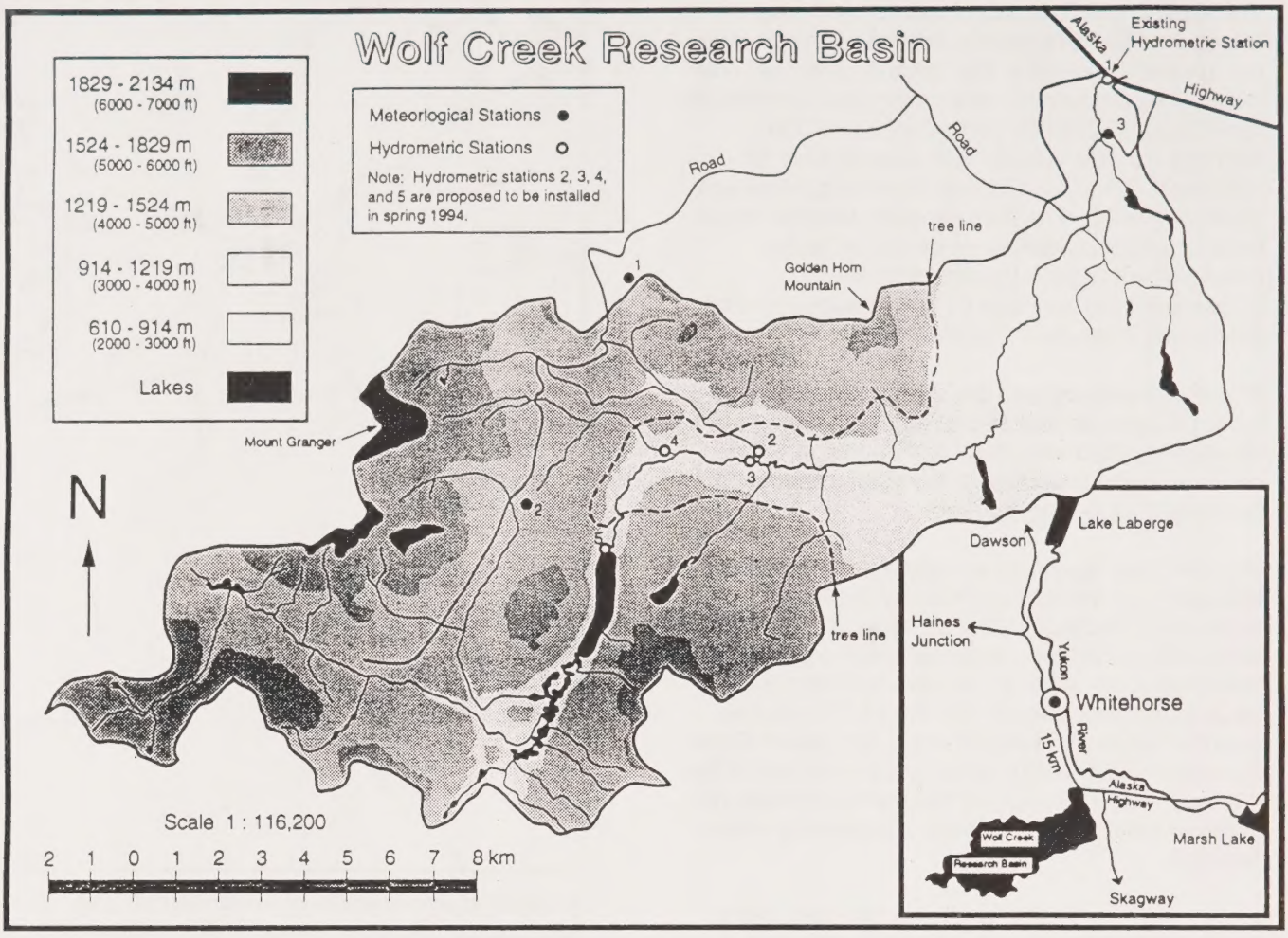
Figure 1: Location plan



situated at an elevation of 1300 metres. The geological makeup is primarily sedimentary in nature with a mantle of glacial till varying from a thin veneer to a depth of one to two metres. Soils are primarily poor forest and tundra types with relatively good drainage. The basin is within the discontinuous/scattered permafrost zone with sporadic permafrost at higher elevations. The watershed has three broad vegetation cover types of about equal proportions. These include low bush tundra, high bush taiga and boreal forest consisting of mixed spruce, pine and poplar. Treeline is located roughly at 1300 metres.

The basin has a sub-Arctic continental climate which is characterized by a large variation in temperature, low relative humidity and relatively low precipitation. Mean annual temperature is in the order of -3 degrees C. with a summer and winter monthly range of 5 to 20, and -5 to -20 degrees C. respectively. Summer and winter extremes of 25 and -40 degrees C are not uncommon. An Arctic inversion is common during the winter months when air temperatures increases with elevation. Mean annual precipitation is 300 to 400 mm per year with approximately 60 percent falling as rain.

Figure 2: Wolf Creek Research Basin



Basin response is typical of a mountainous subarctic stream. Streamflow response is characterized by peak flows of 10 to 20 m^3/s in late May or early June due to snowmelt, with low flows occurring in March. Due to the significant lake storage and the proximity of Wolf Creek to the Gulf of Alaska, minimum winter flows are estimated to be relatively high, in the order of 0.4 m^3/s. The basin is susceptible to intense summer rainstorm events which produce secondary peaks.

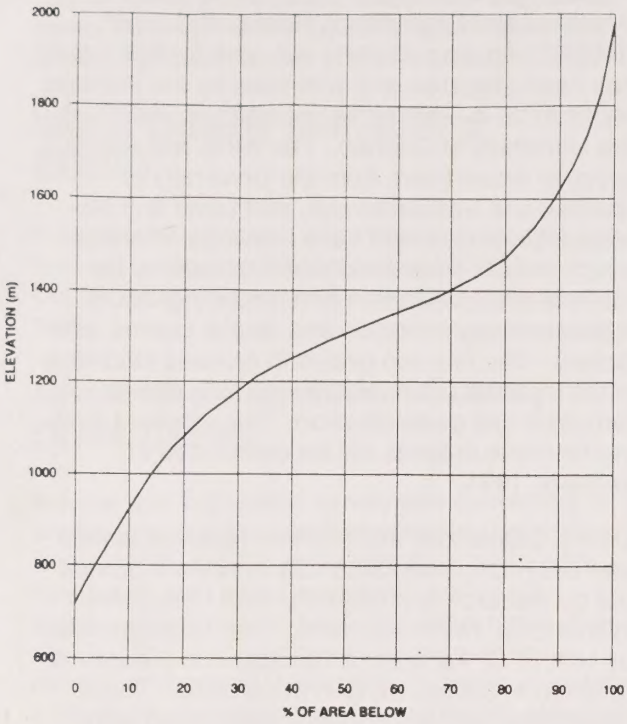
OBJECTIVES

The Wolf Creek Research Basin Project was initiated largely as a result of DIAND's AES program with support from NHRI. The underlying goal of the AES is to "preserve and enhance the integrity, health, biodiversity, and productivity of our Arctic ecosystems for the benefit of present and future generations". This goal was to be achieved using an ecosystem approach through four areas: contaminants, waste, water and environment/economy integration. The primary objective of the water component is to establish an enhanced water resource management regime through improved knowledge and decision making.

Specific objectives included characterizing the hydrologic and water quality regimes of a Yukon subarctic mountain stream, and, using the basin as a dedicated location for carrying out applied studies. The Department carries out the flood forecasting for the Territory and would benefit from a dedicated area to determine various abstraction rates and amounts including evapotranspiration, interception, sublimation and infiltration to calibrate hydrologic flow models; as well as improving our understanding of the energy and water balance processes. This information then can be readily transferred to other areas in the Territory.

Significant support and assistance was provided by NHRI, who have a strong research interest in developing improved snow accumulation, snowmelt and regional evapotranspiration routines for hydrologic modelling purposes. Field process

Figure 3: Hypsometric curve for Wolf Creek



studies directed towards this goal are being conducted by NHRI at sites in the southern boreal forest, northern prairies and a subarctic-tundra transition region near Inuvik. Presently, no upland "headwater" sites are being studied, despite the controlling effect that runoff from these uplands have on river discharge in large basins such as the Yukon and Mackenzie.

BACKGROUND

The establishment of a research watershed in the Yukon has been a topic of discussion amongst the scientific community for several years. During 1990 the YTG Department of Renewable Resources initiated a study to assess the feasibility of establishing a field research station in the Yukon. The objectives of the study were to examine the utility of a research station in furthering scientific and policy studies, and to determine the scope and costing of such a station. The focus of the study was oriented towards forestry issues. The study concluded that there is a role for a research station of this type but it would have to compete with existing research units.

Several consultations took place with interested interdepartmental parties during 1990 and 1991. These included Environment Canada's NHRI, Environmental Protection Service and Atmospheric Environment Service, Fisheries and Oceans Canada, Agriculture Canada, Yukon Territorial Government (YTG), The Yukon Electrical Company Limited (YECL) and Yukon College. A formal meeting under the auspices of the Yukon Climate Advisory Committee took place on March 6, 1991. At that meeting it was decided that a general climate change focus would be most appropriate for the research area.

Significant support for a research watershed was provided through the Arctic Environmental Strategy (AES), the Department's companion to the Green Plan which was introduced on April 3, 1989. With a six year timeframe, the primary objective of the water component is to establish an enhanced water resource management regime through improved knowledge and decision making. This objective was to be achieved through the establishment of a comprehensive water monitoring network, an increased understanding of water quality and quantity, monitoring changes in water quality and quantity over time and the establishment of a Yukon water quality laboratory. The development of specific programs was to include input from native groups and the general public. A consultative public workshop was held in Whitehorse on January 10, 1992. A major conclusion of the workshop was that applied studies are needed as an extension to the baseline programs. Many such studies could be carried out in a research watershed or field research station. A research facility of this type would allow for the integration of scientific disciplines as well as offering cost sharing opportunities.

Several meetings and discussions took place with Yukon College during the spring and summer of 1992 culminating in an agreement in principle to develop a cooperative arrangement to maintain a basic data collection network within the watershed. This initiative would be used as an educational exercise within the College's Renewable Resources Program. The program administrator is willing to modify class schedules to accommodate data collection needs.

During August of 1992, the circumpolar Northern Research Basins workshop and Symposium was held in Whitehorse and Dawson City. International interest in a research facility in the Whitehorse area was expressed.

A decision was made to proceed with the basic instrumentation of the watershed as an AES initiative. A hydrometric station was established in the lower reaches of the basin during the fall of 1992. Interest and support was also provided by the Contaminants Section which wishes to establish several monitoring stations within the basin. The National Hydrology Research Institute expressed interest in carrying out research activities within the basin. Specific activities would potentially in-

ude blowing snow analyses, water balance studies and streamflow model development and calibration.

PROJECT DEVELOPMENT

A reconnaissance survey was carried out by DIAND and NHRI in March 1993. The survey included snow survey and leaf canopy density investigations. Potential sites for the establishment of hydrometric and meteorologic stations were assessed.

With the foundation laid it was now possible to proceed with specific project design elements. Further interest and support was forthcoming from several organizations. An informal agreement was arranged between DIAND and NHRI to engage in collaborative research activities. DIAND would provide the basic capital equipment for three meteorological stations while NHRI would provide some specialized instrumentation and assist in station design and installation. Letters of intent were exchanged and an arrangement was made to enter into a formal Scientific Cooperation Agreement as the project progressed. Several scientists indicated an interest to carry out research within the basin in the areas of evaporation/evapotranspiration, distributed hydrological modelling and snow accumulation, sublimation and melt. At the same time an offer of assistance from AES's Hydrometeorlogical Processes Division, in data analysis was received.

Contact was established with the Northern Research Institute (NRI) at Yukon College in Whitehorse who were interested in providing logistical and administrative support in the project where possible. NRI's specific interest lies in promoting the utilization of local technical or field staff preferably from within the college community.

Potentially significant support was provided through the Canadian Global Energy and Water Cycle Experiment (GEWEX) Program. An initiative of the World Climate Program, the project has the major goal of improving the ability to model energy and water balance processes and assess the sensitivity of these processes to climate change. At the North American scale two simultaneous projects are underway to study the Mississippi and Mackenzie River Basins. The central objective of the Canadian study is to develop the ability to model energy and water balance in the north at spatial and temporal scales of 100 square kilometres and one month respectively. Specific study sites include Trail Valley and Havikpak Creeks near Inuvik, and Beartrap Creek in Prince Albert National Park. Wolf Creek near Whitehorse has been proposed as a third GEWEX study site. A collaborative research proposal for Natural Sciences and Engineering Research Council (NSERC) funding to carry out work in Wolf Creek has been prepared and submitted by the Institute National de la Recherche Scientifique (INRS) at the University of Quebec. The INRS represents a group of researchers from the University of Quebec and Saskatchewan, and Laval and McMaster University who have individual interests which include watershed runoff modelling, permafrost characterization and modelling, and a watershed segmentation and spatial scaling component. The first two deal with process modelling while the third is concerned with data characterization and generalization. The extent of funding for these projects will be announced in January, 1994.

During September, 1993 further reconnaissance and basin characterization surveys were carried out by research and technical staff from DIAND Whitehorse, NHRI and INRS. Input was provided by NRI,DFO, Agriculture Canada who are also interested in collaborating in the project. Three meteorological stations were established within the three elevation-vegetation zones. The stations have been instrumented to monitor air temperature, rainfall, snowfall, wind speed, humidity, incoming and outgoing shortwave radiation, net radiation, barometric pressure, snow depth, blowing snow transport, soil temperature and soil heat flux. The instrumentation is controlled by solid state dataloggers and powered by solar panels. Snow survey courses were also established at each site.

RESEARCH ACTIVITIES

1992-93

Watershed Characterization DIAND/NHRI

Watershed and sub-basin boundaries were delineated and mapped as well as access routes and vegetation zones. A preliminary characterization of the hydrology, climate and physiography was carried out.

Aerial Survey DIAND/NHRI

An aerial survey of the watershed was carried out during which approximately 50 oblique and vertical photographs were taken illustrating vegetation cover and density. Digital grey-scale images of the basin were also obtained using an NHRI digi-

tal camera in a format suitable for computer enhancement and image analysis. Four vegetation zones were identified: mixed forest, coniferous forest, high bush tundra and short bush tundra.

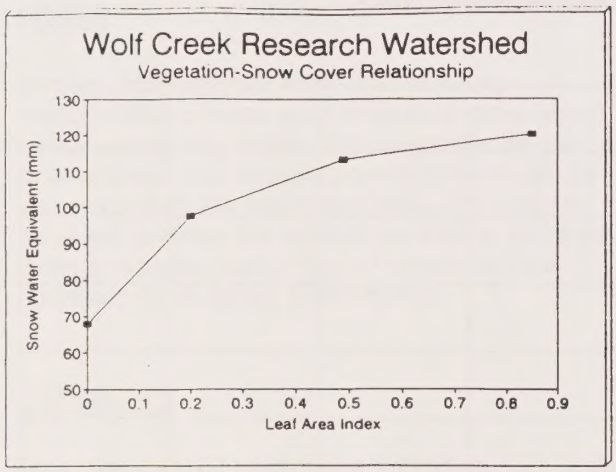
Water Quality Monitoring DIAND

A benthic invertebrate sampling program was carried out on four occasions during 1992/93. Coliform bacteria were also sampled at these times.

Snow and Vegetation Survey DIAND/NHRI

A snow and vegetation survey was carried out in the basin using the stratified sampling technique. Snow depth, density and water equivalent were measured, and a leaf area index and canopy closure calculated for four vegetation zones (figure 4). The study indicated snowcover to be directly proportional to vegetation cover; therefore, a decrease in snowcover with increasing elevation was observed (figure 5).

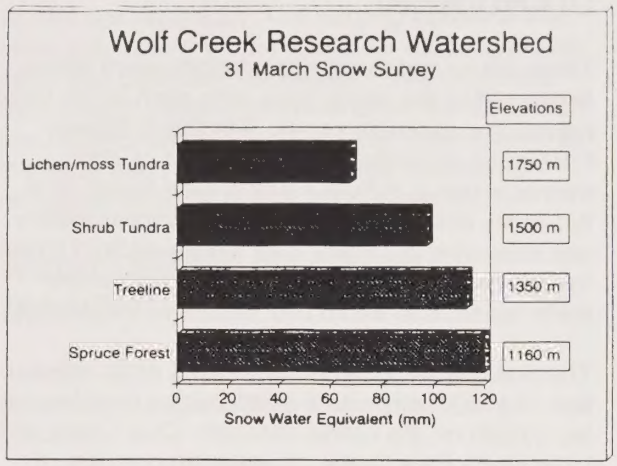
Figure 4: Snow Water Equivalent as a Function of Leaf Area Index in the Wolf Creek Research Watershed



Hydrometric Station Installation DIAND

A hydrometric station was established at the Alaska Highway crossing of Wolf Creek for activation in the spring of 1993. The station will operate as a continuous, year round station.

Figure 5: Snow Water Equivalent as a Function of Elevation and Vegetation in Wolf Creek Research Watershed



1993-94

Watershed Characterization DIAND/NHRI

Watershed characterization will continue with the collection of baseline information on soil types and structure, surficial geology, vegetation cover and presence of permafrost. This data will be extracted from existing sources, field surveys, and satellite imagery. The use of NOAA daily satellite imagery to determine the depletion of snowcover in the basin will be investigated from historical satellite images.

Streamflow Monitoring DIAND

The hydrometric station at the Alaska Highway crossing was activated in the spring and will be operated continuously (figure 6). The basin was surveyed to determine further hydrometric monitoring needs. Two additional hydrometric stations will be established as Phase 1 of the hydrometric monitoring program in 1994 on upper Wolf Creek below Coal Lake and at the mouth of North Fork Creek.

Water Quality Monitoring DIAND

Water quality sampling was initiated at the lower Wolf Creek station in the spring and will continue on an ongoing basis for routine parameters and metals as well as coliform bacteria. Isotope samples have been collected since September.

Meteorological Station Installation DIAND/NHRI

Three major meteorological stations were established within the study area, one each in the three elevation-vegetation zones. The Black Spruce Forest site is located at an elevation of 750 metres within a mature black spruce forest on a flat valley bottom near Wolf Creek approximately one kilometre upstream from the lower Wolf Creek hydrometric station. The 13 metre instrument tower extends to within two metres of the canopy.

The Buckbrush Taiga site is located at an elevation of 1250 metres on a gentle slope near the valley bottom on the divide between Coal Creek and Little North Fork Creek. Vegetation consists of 1 to 2 metre high willows and alders with scattered spruce patches spaced approximately 30 metres apart. A five metre high instrument tower extends above the vegetation.

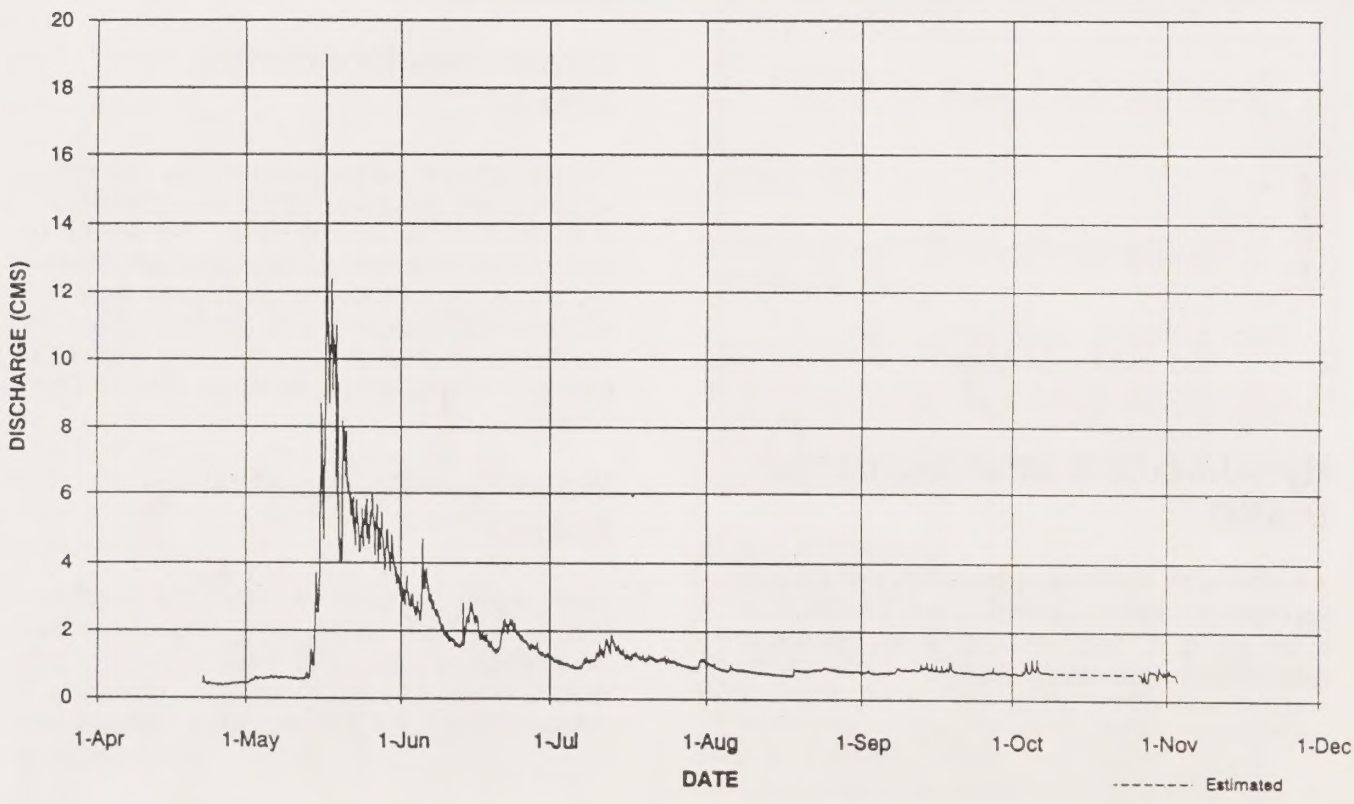
The Alpine Tundra site is located at an elevation of 1615 metres on a wind swept high alpine tundra plateau along a drainage divide at the northern edge of the basin. A rounded 100 metre high hilltop lies 50 metres to the east of the station. Vegetation is sparse consisting of mosses and lichens with occasional patches of scrub willow no more than 0.2 metres tall. Boulders of up to 1 metre tall are scattered on the plateau. A 3 metre instrument tower extends above the ground.

Each of the stations have been instrumented to record air temperature, rainfall, snowfall, wind speed, humidity, incoming and outgoing shortwave radiation, net radiation, barometric pressure, snow depth, blowing snow transport, soil temperature and soil heat flux. Precipitation instrumentation includes a tipping bucket rain gauge and a nearby Nipher gauge. The instrumentation is controlled by solid state dataloggers and powered by solar panels. Twenty-five point snow courses will be sampled monthly throughout the winter.

Snowpack Monitoring DIAND

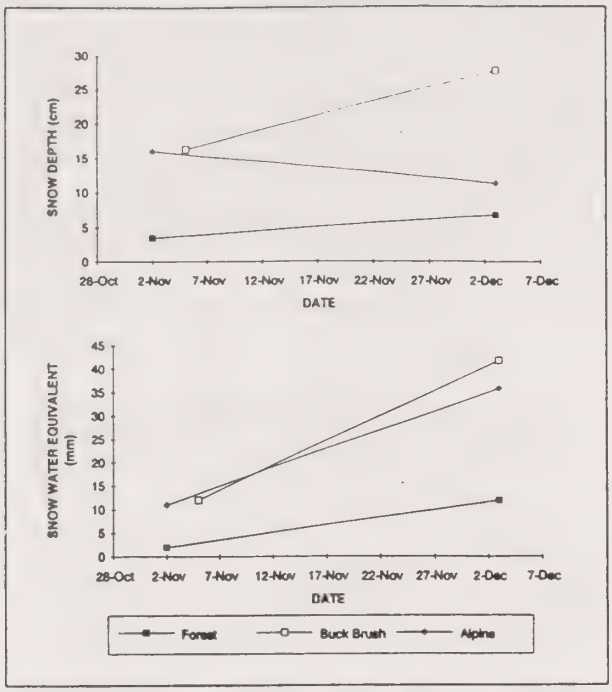
Monthly snow surveys were initiated November 1 and will continue through the snowmelt period. The surveys will provide information on snowpack accumulation and depletion in each of the elevation-vegetation zones. Snow depth, density and

Figure 6: Wolf Creek Hydrograph



water equivalent parameters are being monitored (figure 7). Snow samples for chemical contaminant and nutrient analysis are also being collected at each site.

Figure 7: Wolf Creek snowpack characteristics



Wind Redistribution of Snow NHRI

An experiment on the wind transport and redistribution of snow over irregular tundra terrain will be initiated by NHRI. Blowing snow particle counters and fast response anemometers will be used to collect the necessary data. The experiment will address the vertical removal of snow particles and water vapour from the near surface boundary layer during snow storms.

1994-95

Proposed DIAND studies are subject to AES funding limitations. NHRI participation in these activities are subject to budgetary and strategic planning approval.

Streamflow Monitoring - Phase I DIAND

Two additional hydrometric stations will be established as Phase 1 of the hydrometric monitoring program in 1994 on upper Wolf Creek below Coal Lake and at the mouth of North Fork Creek. The upper Wolf Creek station has a drainage area of approximately 95 km^2 and is largely controlled by Coal Lake while North Fork Creek has an approximate drainage area of 25 km^2 and contains no storage (figure 2). The varying scales of the three sub-basins will be useful for model development and calibration purposes. The proposed hydrometric development will allow the examination of the storage effects of Coal Lake as well as the separation of the tundra/taiga dominated response from the mixed forest response.

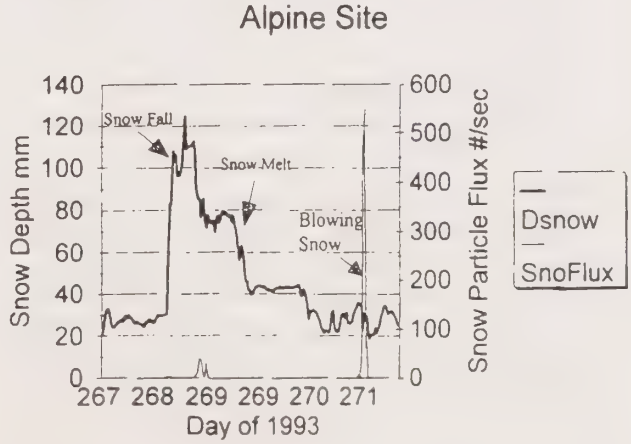
Water Quality Monitoring DIAND

Weekly water quality sampling for routine parameters and metals will continue during 1994/95.

Snow Accumulation and Depletion NHRI/DIAND

Studies in Alaska, Scotland, Wyoming and the northern Prairies show wind transport and sublimation of snow to be an extremely important hydrological processes in open areas, removing up to 75 percent of the annual snowfall from exposed sites. While models have been developed for level sites, their application and interpretation in irregular terrain is unclear, particularly the effect of topographic features in partitioning eroded snow into that sublimated and that subsequently deposited as drifts in gullies or as cornices. Snow intercepted by coniferous canopies is exposed to the atmosphere for long periods and can undergo substantial sublimation. In the southern boreal forest 35 percent of annual snowfall can sublimate in this manner, however the amounts are unknown for northern sites. Satellite imagery, manual sampling techniques and existing instrumentation will

Figure 8: Wolf Creek snow depth and flux



be utilized for this project (figure 8). A recording snow pillow installation is also planned for the intermediate buckbrush site.

Snowmelt
NHRI/DIAND

Studies in the Arctic, subarctic, transition and northern prairies show that the disposition of meltwater between runoff, basal ice formation and soil infiltration is governed by the energetics of the snowpack, soil and atmosphere, texture of soil and the depth of snowcover. A northern, upland basin is expected to display melt characteristics that vary with elevation, as many climate, soil and vegetation parameters will correlate with elevation. High elevation zones will have shallow, uneven snowpacks that have undergone severe temperature gradient metamorphism and are cold during melt. Short wave radiation exchange, areal albedo and advection of thermal energy from bare patches onto remaining snow patches are important characteristics of melt in this zone (figures 9 & 10). Lower elevation zone snowcovers are deeper, have exposed vegetation and are warmer during melt. Melt is driven by long wave radiation emission from vegetation and sensible heat. The relative portion of snowmelt water infiltrated or contributing to runoff in the different melt zones is unknown.

Evapotranspiration
NHRI/DIAND

Arctic/alpine environments are known for low evapotranspiration rates. An air mass moving across the watershed will encounter a series of "strips" of lakes, open tundra, taiga and forest surfaces with considerable potential for advection of energy between surfaces. Regional feedbacks may enhance or diminish actual evapotranspiration rates from specific surfaces. A method to aggregate evaporation over the watershed and evaluate the advective energy input to evaporation will be required.

Runoff Modelling
NHRI/DIAND

Development of distributed hydrological models and the physically-based algorithms which comprise these models is necessary to accurately model the flow regimes of ungauged watersheds and to predict flows from watersheds undergoing changing land use or climate. NHRI is in the process of completing a working version of HYDROTEL, a fully-distributed hydrological model. There is a strong research interest in developing improved snow accumulation, snow melt and regional evapotranspiration modules for distributed models. Field process studies directed towards this goal are being conducted by NHRI at sites in the southern boreal forest, northern prairies and subarctic-tundra transition. Presently, no upland "headwater" sites are being studied, despite the controlling effect that runoff from these uplands has on river discharge in large basins such as the Mackenzie and the Yukon.

Figure 9: Wolf Creek energy fluxes

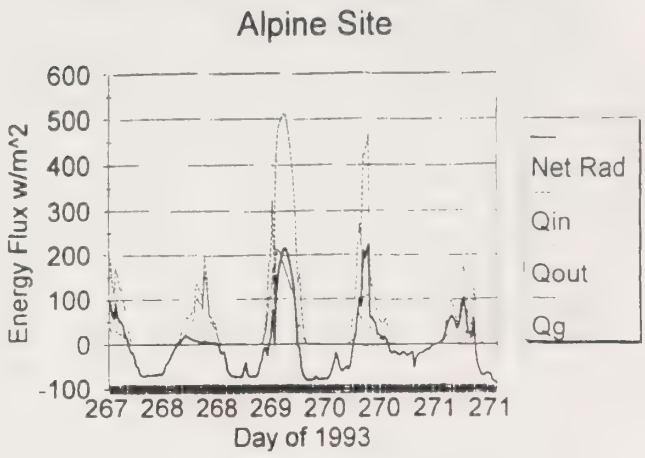
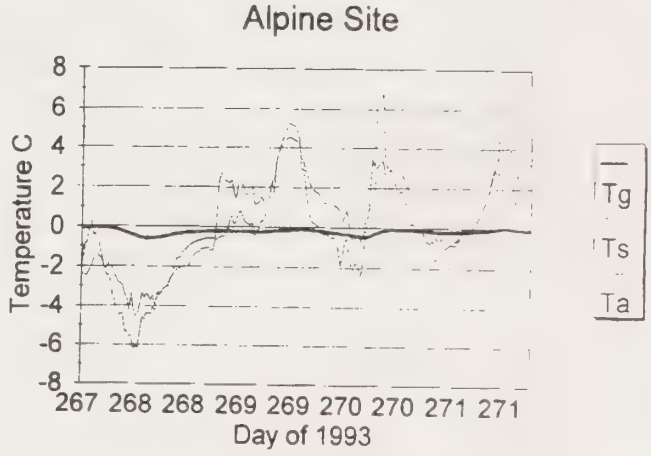


Figure 10: Wolf Creek temperatures



GEWEX Program

The following studies are contingent on NSERC funding through the GEWEX program. The INRS at the University of Quebec has the lead in the overall research program consisting of two projects and subteams with representatives from the University of Quebec, Lavel University, McMaster University, and the University of Saskatchewan. The projects are linked through the use of the Variable Source Area Simulator (VSAS2) runoff model.

Streamflow Monitoring - Phase II INRS/DIAND

If the University of Quebec GEWEX studies proceed as proposed, two additional hydrometric station are planned for the basin. These will be installed on Little North Fork Creek at the mouth and on upper Wolf creek above North Fork Creek. These installations will isolate the ten square kilometre forest/taiga valley drainage by eliminating the tundra/taiga response of Little North Fork Creek as well as the storage controlled response of Coal Lake (figure 2). Doing so will allow the study of a relatively small, predominantly forested, upland basin.

VSAS2 Runoff Simulator INRS

The VSAS2 model is based on the physical processes governing water movement in a basin. Necessary input data include surficial geology, soil hydrodynamic properties, and precipitation or snowmelt. There are no adjustment parameters within the model since it is based totally on basin and soil physical properties. The model predicts water outflow and soil water content for each soil layer and produces storm flow hydrographs for the sub-basins.

Freeze and Thaw Processes of Permafrost and Non-Permafrost Areas INRS/McMaster

The proposed research will model the permafrost and non-permafrost active layer dynamics, notably the water table and frost table conditions for differing terrain within a basin, and couple the outputs to the VSAS2 basin model.

Localizing Data Inputs for Hydrological Models Using Digital Spatial Technologies Laval/Saskatchewan

This project is focused on the use of spatial technologies in model parameterization and the sensitivity of this parameterization on scaling effects and data structures. The objectives of the study are to develop automated techniques for delineating hydrologically meaningful watershed segments from digital elevation models, to map the spatial variability among soil and vegetation characteristics as estimated using digital spatial technologies and to transfer fine scale data to large basins using developed techniques.

DISCUSSION

The Wolf Creek Research Basin project was initiated in 1992 with funding provided by DIAND's AES program, and significant support from NHRI. Specific DIAND objectives included characterizing the hydrologic and water quality regimes of a Yukon sub-Arctic mountain stream, and, using the basin as a dedicated location for carrying out applied studies. NHRI have a strong research interest in developing improved snow accumulation, snowmelt and regional evapotranspiration routines for hydrologic modelling purposes in a mountain environment. Other agencies are also interested in collaborating in the project, notably INRS at the University of Quebec, who represent a group of researchers from several Canadian universities, and have a proposal through the World Climate Research Program's GEWEX program, to carry out research in the basin. Yukon College and the Northern Research Institute are also interested in cooperating where possible.

There is considerable interest for the project, and it appears to be developing a momentum of its own. Logistically the project is very attractive since it is located within thirty minutes of Whitehorse. The basin is readily accessible in the summer and winter and technical and scientific support staff are available in Whitehorse.

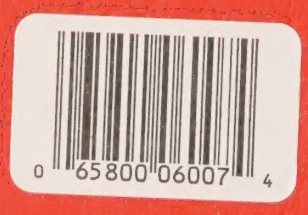
ACKNOWLEDGEMENTS

This project could not proceed without the ongoing dedicated technical and scientific support from Glenn Ford, Martin Jasek and Kerry Paslawski, DIAND, Whitehorse. John Pomeroy, NHRI contributed significantly to the overall study design as well as having a key role in many other components of the project. The installation of the meteorological stations relied heavily on the invaluable technical expertise of Cuyler Onclin and Newell Hedstrom, NHRI. Significant assistance was provided by Raoul Granger and Terry Krauss, NHRI, and Jean Stein, INRS. The water quality monitoring is being carried out by Laura Spicer, DIAND. The cooperation of Mike Winter and Ray Schuler, National Defence Canada, in siting the lower meterological station is greatly appreciated. Input and ideas from Norm Easton, NRI, on project development is appreciated. This report was prepared by J Richard Janowicz with significant contributions from John Pomeroy. Martin Jasek largely carried out the photographic and graphic components of the report. The layout and reproduction of the report was carried out by Diane Nikitiuk. The assistance and cooperation from numerous other agencies is gratefully appreciated.

COOPERATING AGENCIES

Indian and Northern Affairs Canada - Yukon Region
Environment Canada - National Hydrology Research Institute
Environment Canada - Atmospheric Environment Service
Northern Research Institute
University of Quebec - Institut National de la Recherche Scientifique
Laval University
McMaster University
University of Saskatchewan
Yukon College
Agriculture Canada
Fisheries and Oceans Canada
National Defence Canada
The Yukon Electrical Company Limited
The Yukon Territorial Government

Funding for this project was provided by DIAND's Arctic Environmental Strategy Program with contributions from NHRI.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